A

Technical Memorandum

To: *Eric Hiser – Confidential Attorney Client Privilege*

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Subject: *Wyoming State Geological Survey, Open File Report 06-02, Powder River Basin Desalination Project Feasibility*

Summary

CDM completed a broad-level review of the Wyoming State Geological Survey Open File Report 06-02, "Powder River Basin Desalination Project Feasibility", April 2006. In general, the proposed approach of providing centralized treatment of CBNG produced water for beneficial reuse has a lot of merit. However, in order to evaluate the proposed approach further, there are several issues that need to be addressed. Following is a summary of some of the major issues based on CDM's review:

- The amount of time required to complete the feasibility study, prepare an EIS, gain access agreements and easements, and construct the system on a very rigorous schedule would be several years. (Industry contacts reported that the Wyoming DEQ estimated this time-frame to be more than four years during a meeting held on April 7, 2006 to discuss this and related water management issues in Casper.) This time period would be extended if there is litigation between states regarding trans-basin diversions.

- Treatment technology, particularly brine disposal and treatment system costs, requires a more detailed analysis and cost estimate.

- Transmission cost estimates appear to be significantly low and should be revised.

- Gaining financial support from users, coordinating financial issues and grants as well as coordinating development timing requires a more detailed analysis.

Treatment Issues

Some of the primary technical issues that need to be addressed in more detail include:

- Flow and Water Quality Fluctuations. The quality of water produced during CBNG development varies widely throughout the basin and over the lifetime of the CBNG well (ALL Consulting, 2004). The same holds true for flow. Economics presented in the report assumes that the system is operating at full-capacity at all times, and does not appear to consider production declines. However, designing a system to operate at full capacity 100 percent of the time will be difficult. Consequently, the economics need to consider the cost of maintaining idle capacity. In summary, variations in flow and water quality over time will significantly affect the design and cost of treatment operations.

- Feed Storage Pond Issues. The assumed method for managing fluctuations in flow and quality of feed water is by using a storage pond. Using a storage pond upstream of the RO system will help stabilize fluctuations in both flow and water quality, but it also increases the potential for membrane fouling. CDM's general experience is that collecting and storing groundwater in a pond ahead of an RO system significantly increases the potential for membrane fouling due to aeration, precipitation of iron and minerals and biological growth on the membrane surface, which results because oxygen is added. During the winter, the water temperature will also drop, making RO operations less efficient.

- The report assumes RO will be the chosen treatment method. However, there is only one commercial RO currently operating in the Powder River Basin (PRB) while more than a dozen commercial ion exchange (IX) systems are currently operating. The report fails to, and should, consider treatment alternatives on a broader scale.

- Pretreatment. Selecting the proper pretreatment system for RO is the key to efficient, cost-effective treatment over time, especially when treating industrial water sources at high recoveries, such as in this case. The report does not address the necessary pretreatment steps so it is unclear whether the capital and O&M costs for pretreatment are included. Based on CDM's analysis of the typical water quality in the PRB, the following pretreatment steps will be required:

    1. Pond storage to attenuate flucations in flow and water quality

    2. Primary and secondary filtration to remove coal fines and other suspended solids

    3. Acid addition to reduce fouling from mineral salts

    4. Antiscalent addition to minimize fouling from iron, barium sulfate, calcium carbonate and calcium fluoride

    5. Chlorination or ozonation to reduce bacteria formation and system biofouling

- Post-treatment. The treated effluent will contain very high concentrations of carbon dioxide, which is corrosive to carbon steel pipelines. Consequently, a degasifier followed by pH adjustment will be required prior to distribution. It is not clear whether .the report includes the capital and O&M costs for post-treatment.

- Brine Disposal. A recognized deficiency in this report is associated with disposal of the brines generated by treatment. Brine disposal represents the single most difficult environmental, technical and economic issue related to the use of RO (and IX) treatment technology in the PRB. This is evidenced by the fact that so many different configurations of RO (and IX) treatment have been, or are being, developed and tested. While meeting treatment objectives is relatively straight forward with these technologies, managing the disposal of brine in an environmentally, cost-effective manner is not.

  The report projects approximately 10 percent of the treated volume will be generated as a high TDS brine. The report identifies the primary technologies as evaporation ponds, heated evaporation tanks or underground injection. Each of these technologies has limitations and will involve significant costs. The evaporation technologies will need to consider climatic factors that limit evaporation rates during the winter season and may require construction of significant lined storage reservoirs. Use of underground injection would require a subsurface reservoir that already contains high TDS water. Current commercial injection options available in the vicinity are limited, expensive to haul to and would rapidly be overwhelmed by the size of the treatment system being contemplated.

  Options for disposal of brine in the PRB are discussed briefly as follows:

  1. Pond Evaporation. This option involves constructing a lined impoundment to evaporate the concentrated brine. The primary disadvantage of this option in the PRB is the low net evaporation rate, which results in large surface area requirements. For example, CDM determined that a 1 acre pond is required to evaporate about 1.5 gpm near Sheridan. At the same net evaporation rate, a 1,200 acre pond would be required to evaporate the brine from one 600,000 BPD treatment plant. To accommodate the 39 CFS total treatment capacity being considered in the report, it would require 1200 acres of evaporative ponds.

  2. Deep Well Injection. In some basins, this is the most common method of disposal. However, previous studies (CDM, 2004) have indicted that injection opportunities are limited in the PRB. This option is also very expensive, both in terms of capital and O&M costs.

  3. Mechanical Evaporation. The energy costs required to evaporate water are roughly 10 times the cost of concentration by RO. This option is limited to relatively small flows

and is likely cost-prohibitive for this application. Like natural evaporation, the cost of disposing of the dried salt also needs to be considered.

Cost

Some of the primary cost issues that need to be addressed in more detail include:

- Capital Costs. CDM completed a preliminary, order-of-magnitude cost estimate of the RO treatment system. In general, the cost of $50 million (M) for a 600,000 bbl/day plant is reasonable for the primary treatment components. However, a projected RO plant cost analysis needs to include "site factors" or those costs associated with locating and constructing the plant. The Table C costs are of a magnitude that would indicate they only include process equipment and installation of that equipment. Site factors that affect the costs include items such as permitting, land acquisition and access costs, the complexity of construction and construction cost escalation factors if the location is remote, storage ponds, post-treatment and distribution pumping. These factors can add 50 to 100 percent to the cost of the process equipment and its installation.

- Capital Costs per Barrel. While the overall capital cost appears in-line, the capital cost per barrel treated appears to be an order of magnitude low. Table B indicates that the cost per 1,000 barrels treated is $2.27 for a 600,000 bbl/day plant for lifetime treatment of 22 billion barrels produced. However, it would take 100 years for this size of plant to treat this much water. The expected life of the plant is in the 20- to 30-year range. A more accurate and reasonable estimate, assuming a 20 year life, would be about $11 per 1,000 barrels treated.

- Operating Costs per Barrel. The report indicates that the processing cost will be about $0.063 per barrel treated for a 600,000 bbl/day RO plant. CDM completed an independent analysis of this cost and determined that the operating costs for pretreatment, maintenance and labor are in this range.

- Total Cost per Barrel Treated. The report indicates that the total treatment cost is in the range of $0.08 to $0.10 per barrel treated, including the pipeline and treatment plant. However, based on the corrected capital cost numbers, the cost for treatment alone is about $0.084 per barrel. After adding the cost of gathering, storage, and distribution, the total cost will be much higher than the reported $0.10 per barrel.

- Additional Cost for Brine Disposal. The cost of brine disposal has not been determined and is beyond the scope of this study. However, previous studies indicate that the cost of brine disposal can be as high as 63 percent (CDM, 2004) of the total treatment cost. For example, CDM's estimate in the Kuiper's study showed that the cost of brine disposal alone was $0.46 per barrel treated. Combining this with the cost of treatment ($0.062 per barrel), the total treatment costs with brine disposal under this one scenario, could be as high as $0.52 per barrel treated. Costs could be even more depending upon distance to facilities, and other factors.

- Funding Issues. The report assumes that funding could occur via a combination of bonds for construction, user fees for disposal and income from sale of treated water. No provision for bond interest is noted in the presented numbers. In many cases, operators in the basin currently have means in place for disposal of water from ongoing operations. If the cost of collection and disposal of the generated water under this scenario is greater than the current costs, why would operators participate? Furthermore, operators may be reluctant to commit to large dedicated volumes around which to plan such a long-term, mega-project when their needs are imminent. Potential users of the treated water also have current local water management solutions in place that would compete on a cost basis with the proposed approach. Since water production is assumed to decline over time, a long-term supply is not ensured, thus users may be less likely to make any modifications to operations to use this new source of water. Also, as PRB operating costs continue to climb, operators may choose to allocate a greater portion of fixed development budgets elsewhere, thereby reducing PRB development and their ability to meet large water volume commitments.

Pipeline/Transmission Issues

Pipeline costs are also estimated in the report. Assuming that the costs per mile are correct, the conclusion that pipeline costs are critical to the project(s) is also correct. The various scenarios for the location of a desalination plant, or multiple desalination plants, need careful input from all potential stakeholders for the project to be a success. Three scenarios are presented; the report states that they are the "most viable options" and focuses on them. The next level of a feasibility study will need to drill down into these three scenarios to verify concentrate disposal costs, improve treatment facility cost estimates by taking into account the site factors in each these scenarios, finalizing facility size at each location (the report assumes one size fits all), and verifying the end use for each location. Additionally, further work should contemplate if synergy between combinations of sites is feasible, or if each site needs stand alone economics. Highly variable water qualities requiring variable treatment efforts and variable distances to a trunk pipeline must also be considered when determining what fee would be charged each operator contributing water to the line.

Transmission Pipeline Cost

Material and installation costs seem unrealistic in the present economy. The report assumes 48 inches as a basis using velocity criteria. The most economical pipe size would have to consider topography, pumping, etc. and should be project specific. A unit cost of $225 per linear foot (LF) is quoted. A reference transmission pipeline project near the Denver metro area is offered with the following statistics:

- Diameter: 48 inch
- Length: 31.3 miles
- Product: Raw and Potable Water
- Operating Pressures: 100 to 290 psi
- Cost: $52 M
- Engineering Cost (Design and Construction): $5M
- Unit Cost: $345/LF (with engineering)
- Completion: Anticipated in August 2006

The reference project is located near developed areas, but generally is in rural environments. Approximately five major bores under highways, railroads, etc. and six minor bores are included. Of the $52 M, the pipe materials portion was $22.5 M and the steel coil was pre-purchased in advance of construction to save on escalating costs for steel. Additionally, there is a large steel pipe manufacturing facility located in the Denver area that allowed the project to benefit from low transportation costs. There are no local or regional plants near the PRB and this additional cost should be factored in.

Another reference project:

- Anadarko – Re-inject Coal Bed Methane Water Into Aquifer
- Pipe Diameter: 24-inch
- Length 48-miles
- Cost: $50 M

A portion of this project cost may be associated with the re-injection well, but apportioning the entire amount to the pipeline results in a unit cost of $197/LF. To make this more directly comparable to a 48-inch pipeline, this can be further reapportioned to cost per linear foot per inch diameter or $8.22/LF per inch diameter. This compares with the Denver reference project at $7.18/LF per inch and the projection of the Feasibility Report of $4.69/LF per inch.

Discussions with NW Pipe Company representatives indicate that steel pricing has escalated approximately 7.5 percent in the last year and a 7 to 10 percent increase is anticipated in the next year.

Pumping Cost

It appears that no pumping requirements were included for treatment or conveyance. There would be substantial capital and O&M costs associated with pumping. The desalination or RO process generally requires boosting pressures across the membranes in the 100 to 200 psi range. Most of this pressure is lost across the membranes and would require additional pumping into the pipeline. Likewise, unless all pipelines can be configured to flow by gravity (positive elevation head), pumping will be necessary and may require supplemental booster pumping stations at locations along the pipeline. This will require additional land acquisition, permitting and power. At remote locations, it may be necessary to generate power locally.

Using the cited pipe size of 48-inch and flow of 15,750 gpm, friction losses in the pipeline would be approximately three feet per mile. Accounting for valves, bends and other minor losses in the piping, this figure could easily double. If the pipeline must gain elevation on the way to the outfall point (whether crossing local topography or an outfall higher in elevation than the starting point), static head requirements must also be included, further increasing the need for and cost of pumping. Using high level planning sources for estimating capital costs, a typical service water pumping station providing 15,750 gpm of pumping capacity would cost approximately $3.5 M per station, not including engineering, land acquisition, permitting, electrical power, or other site or engineering specific conditions that could further impact costs.

Gathering Collection Pipelines

This issue is not mentioned anywhere in the feasibility study. Presumably, a network consisting of many miles of smaller pipelines would be required to convey water from the well sites to a larger transmission pipeline. There could be significant costs associated with these facilities.

Constructability

There is no discussion in the report about the constructability of a pipeline along the corridor selected.

Permitting/Scheduling Issues

Environmental Reviews

The engineering and geologic issues of the proposed transmission pipelines require significant investigation. Are lift stations required, are the soils conducive to a buried line, what size and type of pipe is required? Material costs have changed dramatically over the last year. Assessing these conditions will be time consuming and costly and one year is not realistic.

Interstate Agreements

Trans-Basin Diversions will require multi-state cooperation. For instance, even though the Yellowstone Compact discusses surface water and the CBNG development removes groundwater, this will be the issue: Does the removed groundwater have an impact to surface water. That will not be an easy question to answer, and it would be costly to provide enough data to prove that the Trans-Basin transfer of groundwater would have no impact to surface water. In addition to the cost of showing scientifically that groundwater removal will not affect surface water, if the project is litigated between states, the time required to litigate could be significant. Any litigation of this sort likely would be reviewed by the U.S. Supreme Court, which would be a very lengthy process. It is our opinion that Montana would likely object to a trans-basin transfer.

Landowner Agreements

Permitting

The report identifies a period of one year to obtain permits, acquire the ROW, conduct an EIS and prepare the engineering design. This is an unrealistic time frame for a project of this magnitude. Significant siting and engineering studies would be required for the permits and the EIS. It is likely that a combination of private and public land would be required for the pipeline route. Negotiating with multiple entities would be required before actual permitting and preparation of the EIS could proceed. A more realistic time frame that considers these limitations needs to be included in any analysis.

The transmission pipe lines for both treated and saline water will require the completion of an Environmental Impact Statement (EIS). A typical EIS can take one year or more to complete. A detailed cultural and historic resource investigation will be required, an analysis of threatened and endangered species will be required, and landownership and easement issues will be cumbersome. These issues will require significant time to address, likely several years.

Overall Schedule

Overall, the schedule appears to not include significant issues and is likely more aggressive than could be accomplished.

Other

Water Volume

The analysis suggests beneficial uses of produced water, such as municipal supply and irrigation,that are seasonal in nature. The analysis should assess the need for construction of new reservoirs to handle off-season storage, or assess the availability of storage capacity in the available reservoirs.

Water Supply Commitments from Industry

Funding/Revenue (especially off-season revenue for water usage)

The report needs to include input from the industry that is planning to develop or have developed natural gas. Issues of timing of production and current costs need to be considered in the report.

Cost Summary

To provide a basis of comparison, the total cost per treated barrel has been estimated. This total cost was arrived at by adding all the factors discussed above. Costs per barrel were calculated assuming a 20 year plant life. These costs include the following:

- Plant Capital = $0.017 - $0.022 per barrel (including permitting, land acquisition, equipment capital, and other site factors)
- Operating Costs = $0.063 per barrel treated
- Pipeline Capital = $0.05 – $0.06 for pipeline, pumping stations, land acquisitions, and operating costs. This cost is highly dependent on many factors, and could readily increase beyond this range. Based upon Anadarco's past experience with pipeline construction and operation, this cost could be as high as $0.30 per barrel treated.
- Brine Disposal = $0.20 - $0.46 per barrel treated. CDM has estimated that this cost will likely be near the upper portion of this range; however, based on conversations with Anadarco, it may be possible to reduce this cost to as low as $0.20 per barrel.

Based upon these cost estimations, the total cost of treatment ranges from $0.33 - $0.61 per barrel. As discussed above, this is significantly higher than the cost of $0.08 - $0.10 per barrel offered in the PRB Desalination Feasibility Report. In addition, this total treatment cost does not take into consideration several factors, which are discussed below.

Costs Not Included

There remain many costs and project aspects that need to be considered in order to accurately determine the actual total cost of treatment. These were not included in the above estimated total costs due to the wide range of costs, which are wholly dependent on site specific variables. Such items include costs associated with the construction and operation of sedimentation/equalization ponds, pretreatment equipment and post treatment equipment. In addition, costs associated with brine disposal, permitting, and land acquisition need to be further investigated. Costs for these items were included, but are subject to change once site factors are determined. The gathering network and system required to collect and pump the water to the main influent pipe line could be substantial. This cost could potentially double the project pipe line costs.

Water Supply Commitments from Industry

Funding/Revenue (especially off-season revenue for water usage)

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References

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